



Notes on two sympatric species of deep-water Vesicomysidae (Mollusca, Bivalvia) from the central Gulf of California, western Mexico

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Abstract. Two sympatric species of deep-water Bivalvia are reported from the Gulf of California, below the Oxygen Minimum Zone. The most abundant species was *Calyptogena lepta* (385 living specimens, 102 dead shells). The second species, "*Pliocardia*" *stearnsii*, was much less abundant (5 living specimens, 6 dead shells). Environmental data indicates that both species can tolerate mild hypoxic conditions. Size distribution of *C. lepta* indicates that most specimens (75%) were in the intermediate size range (shell length: 13.50 to 23.49 mm). No difference in the length-height relationship (R^2 , 0.9803) was observed between smaller (minimum length, 8.56 mm) and larger (maximum length, 33.39 mm) specimens of this species.

Key words. Western Mexico, Deep sea, *Pliocardia*, *Calyptogena*, *Wareniconcha*, Oxygen Minimum Zone, Vesicomysidae

Resumen. Nota sobre dos especies simpátricas de Vesicomysidae (Mollusca, Bivalvia) del centro del Golfo de California, México occidental. Se registran dos especies simpátricas de Bivalvia de aguas profundas en el golfo de California, por debajo de la Zona del Mínimo de Oxígeno. La especie más abundante fue *Calyptogena lepta* (385 especímenes vivos, 102 conchas vacías). La segunda especie, "*Pliocardia*" *stearnsii*, fue mucho menos abundante (5 especímenes vivos, 6 conchas vacías). Los valores de los parámetros ambientales indican que ambas especies pueden tolerar condiciones de hipoxia leve. La distribución de tallas de *C. lepta* indica que la mayoría de los especímenes (75%) correspondió a un intervalo de tallas intermedia (longitud de concha: 13.50 a 23.49 mm). No se observaron diferencias en la relación longitud-altura de las conchas (R^2 , 0.9803) entre los especímenes pequeños (longitud mínima, 8.56 mm) y grandes (longitud máxima, 33.39 mm).

Palabras-clave: México occidental, Mar profundo, *Pliocardia*, *Calyptogena*, *Wareniconcha*, Zona de mínima de oxígeno, Vesicomysidae

Introduction

Deep-water mollusks from western Mexico have been scarcely studied. Until recently, most records had mostly been obtained from explorations realized by the "Steamer Albatross" that collected samples in water deeper than 200 m off Acapulco, Tres Marias Islands, and Guaymas. The presence of a wide and intense Oxygen Minimum Zone (OMZ) off western Mexico (Helly & Levin 2004, Hendrickx & Serrano 2010) severely limits the vertical distribution of many species (Hendrickx & Serrano

2014, Papiol *et al.* 2016). In many areas, the continental shelf species cannot tolerate oxygen deficiency and are restricted to a depth range of 50-150 m (Hendrickx & Serrano 2010). The OMZ core, where concentrations below 0.2 ml/l prevail, also represents a physiological barrier for shelf species that are unable to colonize deeper water. Similarly, communities living in deeper water, below the OMZ core where oxygen concentrations are higher, are not able to cross the core barrier (Hendrickx & Serrano 2014). As a result, invertebrate communities living

above and below the OMZ core are made of different species (see Zamorano *et al.* 2006, Hendrickx & Serrano 2014, Papiol & Hendrickx 2016).

Based on recent surveys by the Universidad Nacional Autónoma de México (UNAM) in deep waters (TALUD project), a large series of contributions on western Mexico deep-water invertebrates and fish fauna has been published (see Hendrickx 2012, Papiol *et al.* 2016, Cruz-Acevedo *et al.* 2018). Part of the mollusk communities occurring in the Gulf of California and off western Baja California have already been treated in previous contribution (see Zamorano *et al.* 2006, Hendrickx *et al.* 2016, Suarez Mozo *et al.* 2018). The present contribution reports on two sympatric species of Vesicomidae collected during one of these surveys in the Gulf of California. It provides new environmental data, particularly related to the dissolved oxygen content in the deep-sea habitat, and morphological information.

Material and Methods

Samples of mollusks were obtained using a benthic sledge equipped with an outer collecting net of ca 5.5 cm (2 1/4") stretch mesh and an inner net of ca 2.0 cm (3/4") stretch mesh. The sampling area was visited in February 2007 with the R/V "El Puma" (UNAM). Positional coordinates were plotted using a GPS navigation system and depth was measured with a SIMRAD echosounder. Epibenthic water temperature was measured with a Seabird SEB-19 CTD and dissolved oxygen content was estimated with the Winkler method (Strickland & Parson, 1972) using water samples collected by Niskin bottles at bottom level. Specimens were measured to the nearest 0.01 mm with a digital caliper and were deposited in the Regional Collection of Marine Invertebrates (ICML-EMU) at ICML, UNAM, in Mazatlán, Mexico, and in the Santa Barbara Natural History Museum (SBNHM) in California, USA. The supplementary material deposited in the SBNHM was not part of the material examined during this study but is included in Table I. Records from western Mexico were added to the distribution map for this area. In the case of *Calyptogena lepta* (Dall, 1896), the most abundant species collected, size distribution, and length-height relationship are provided.

Results

Vesicomidae Dall & Stimpson, 1901
"Pliocardia" stearnsii (Dall, 1895)

Figure 1

Callocardia stearnsii Dall, 1895a: 693, Fig 1A; 1895b (1896): 17.

Vesicomya stearnsii.- Parker, 1963: Table 1.

Vesicomya stearnsi.- Austin, 1985: 349 (list).

Vesicomya (Vesicomya) stearnsii.- Coan *et al.* 2000: 338, Pl. 69.

"Pliocardia" stearnsii.- Coan & Valentich-Scott, 2012: 540, Pl. 178.

Pliocardia stearnsii.- Johnson *et al.* 2017: Figs. 2, 3.

Material examined. TALUD X, St. 9 (27°52'51"N, 112°15'53"W), February 10, 2007, benthic sledge, 1205-1215 m, 5 live specimens (min. SH/SL, 6.30/7.85 mm; max. SH/SL, 8.90/12.20 mm) (ICML-EMU-12102) and 6 dead shells (min. SH/SL, 7.02/ 8.26 mm; max. SH/SL, 9.74/11.90 mm) (ICML-EMU-12101). Environmental conditions at bottom: water temperature, 3.77°C; dissolved oxygen, 0.31 ml O₂/l.

Distribution and bathymetry. From Vancouver Island (48.4°N), Canada, to Tortuga Island (27.5°N), Gulf of California, Mexico, and to the Gulf of Panama (6°N). From 370 to 3070 m (Coan & Valentich-Scott 2012). Sampling depth of material examined is comprised within the known depth range of the species.

The Smithsonian collection online database contains two lots of this species: the material from the type locality (syntypes, about 15 specimens), USNM-106858, off Point Arena (39.0444°N, 124.104°W), California, USA, Albatross St. 3348, 832 m depth; one dry lot (as *Callogonia stearnsii*), USNM 756650, Albatross St. 3009, East of San Marcos Island, 27.15°N, 111.7°W, Gulf of California, Mexico, 857 fm (1567 m). Parker (1964) reported one capture of *P. stearnsii* (as *Vesicomya stearnsii*) in southern California (station 145): 33°40.5'N, 119°29.3'W, at 1880-1936 m depth, in oxygen concentration of 1.0 ml/l.

The SBNHM collection holds 8 lots, 7 from western Mexico (dry material) and one fluid-preserved sample from the Monterey Canyon, California, USA, collected in 635-2532 m depth (Table I). All the specimens from Mexico are from the Gulf of California (Fig. 2).

Size. The maximum known size of *P. stearnsii* is 46 mm (shell length). The material examined falls into the lower part of the size range known for this species.

Table I. Material of "*Pliocardia*" *stearnsii* (Dall, 1895) and *Calypptogena lepta* (Dall, 1896) in the SBMNH. N, number of specimens; D, W, dry and wet collections. Material from Mexico used in figures 2 and 4.

SBNHM	Locality	Date	Coordinates	Depth	N
<i>P. stearnsii</i>					
135532	Velero IV, st. 11809, E off Isla Tortuga, Baja California	Nov. 27, 1967	27.517°N, 111.567°W	1006.7 fm	20 (D)
149697	Velero IV, st. 11809, E off Isla Tortuga, Baja California	Nov. 27, 1967	27.517°N, 111.567°W	1006.7 fm	3 (D)
135530	Velero IV, st. 11808 E off Isla Tortuga, Baja California	Nov. 27, 1967	27.517°N, 111.583°E	1008 fm	12 (D)
135541	Velero IV, st. 11813, off Isla Tortuga	Nov. 28, 1967	27.517°N, 111.733°W	929 fm	20 (D)
213957	Velero IV, st. 11813, off Isla Tortuga	Nov. 28, 1967	27.517°N, 111.733°W	929 fm	2 (D)
135520	Velero IV, st. 11793, E off Isla Tortuga	Nov. 24, 1967	25.333°N, 109.983°W	1385 fm	3 (D)
123888	Albatross st. 3010, E of Santa Rosalia	Mar 20, 1889	27.396°N, 111.417°W	1005 fm	1 (D)
463030	Monterey Canyon, Ventana Dive 3374	Jun 3, 2009	36.800°N, 122.990°W	635 m	30 (W)
<i>C. lepta</i>					
135503	Velero IV, st. 11791, off Isla San José, Baja California	Nov 24, 1967	25.299°N, 110°W	1330 fm	33 (D)
135540	Velero IV st. 11813, off Isla Tortuga, Baja California	Nov 28, 1967	27.517°N, 111.733°W	929 fm	1 (D)
618177	Guaymas Basin, Alvin Dive 2234	Jun 16, 1990	27.003°N, 111.408°W	2020 m	4 (D)
618200	Guaymas Basin, Alvin Dive 2838	Oct 7, 1994	27.003°N, 111.406°W	2007 m	14 (D)
618187	Guaymas Basin, Alvin Dive 2838	Oct 8, 1994	27.003°N, 111.406°W	2007 m	7 (D)
463129	Guaymas Basin, MBARI Dive T 548	Apr 5, 2003	27.576°N, 111.448°W	1755 m	1 (D)
617150	Guaymas Basin, MBARI Dive T 548	Apr 5, 2003	27.576°N, 111.448°W	1755 m	1 (D)
617131	Guaymas Basin, MBARI Dive T 549	Apr 5, 2003	27.012°N, 111.407°W	2007 m	1 (D)
455120	Hippa Island, ca 42 km off W coast	August 1965	53.550°N, 133.634°W	1921 m	1 (D)

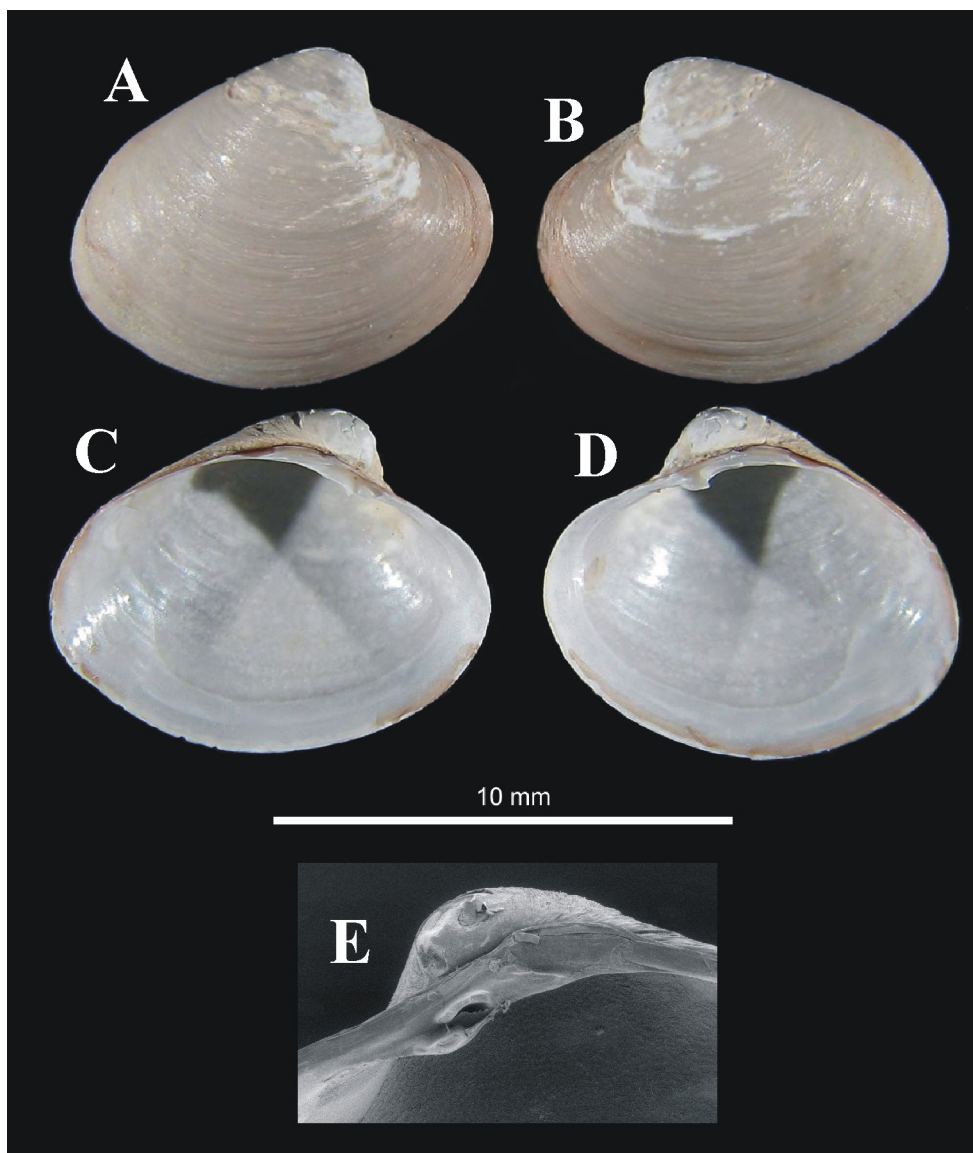


Figure 1. "*Pliocardia stearnsii*" (Dall, 1895). A: right valve, external view; B: left valve, external view; C: left valve, internal view; D, right valve, internal view; E, right valve, detail of hinge (SEM, 20 x).

Calyptogena lepta (Dall, 1896)

Figure 3

Callocardia lepta Dall, 1895b (1896): 17.

Vesicomya (*Vesicomya*) *lepta*.- Keen, 1971: 116, Fig. 260a; Coan *et al.* 2000: 338, Pl. 69.

Vesicomya lepta.- Austin, 1985: 349 (list); Goffredi *et al.*, 2003: 313, Table 1, 314-319 (passim); Hendrickx & Brusca 2005: 206 (list); Krylova & Sahling, 2006: 389.

Wareniconcha lepta.- Krylova & Sahling, 2010: 6.

Calyptogena lepta.- Coan & Valentich-Scott, 2012: 534, Pl. 136; Johnson *et al.* 2017: 353, Figs. 2, 3.

Material examined. TALUD X, St. 9 (27°52'51"N, 112°15'53"W), February 10, 2007, benthic sledge,

1205-1215 m, 385 live specimens (min. SH/SL, 6.51/8.56 mm; max. SH/SL, 25.58/33.39 mm), (ICML-EMU-11722, 11723, 11724, 11725), 6 live specimens (SBNHM 455118), and 96 dead shells (min. SH/SL, 7.24/8.94 mm; max. SH/SL, 17.86/24.06 mm) (ICML-EMU-11721). Environmental conditions at bottom: water temperature, 3.77°C; dissolved oxygen, 0.31 ml O₂/l.

Distribution and bathymetry. From off Oregon (45°30'N), USA, and into the Gulf of California, north to off Bahía Concepción (27°12'N), Mexico. From 850 to 2020 m (Coan & Valentich-Scott 2012). Material examined comes from a slightly northern locality, at a depth comprised within the known depth range of the species.

The Smithsonian collection online database

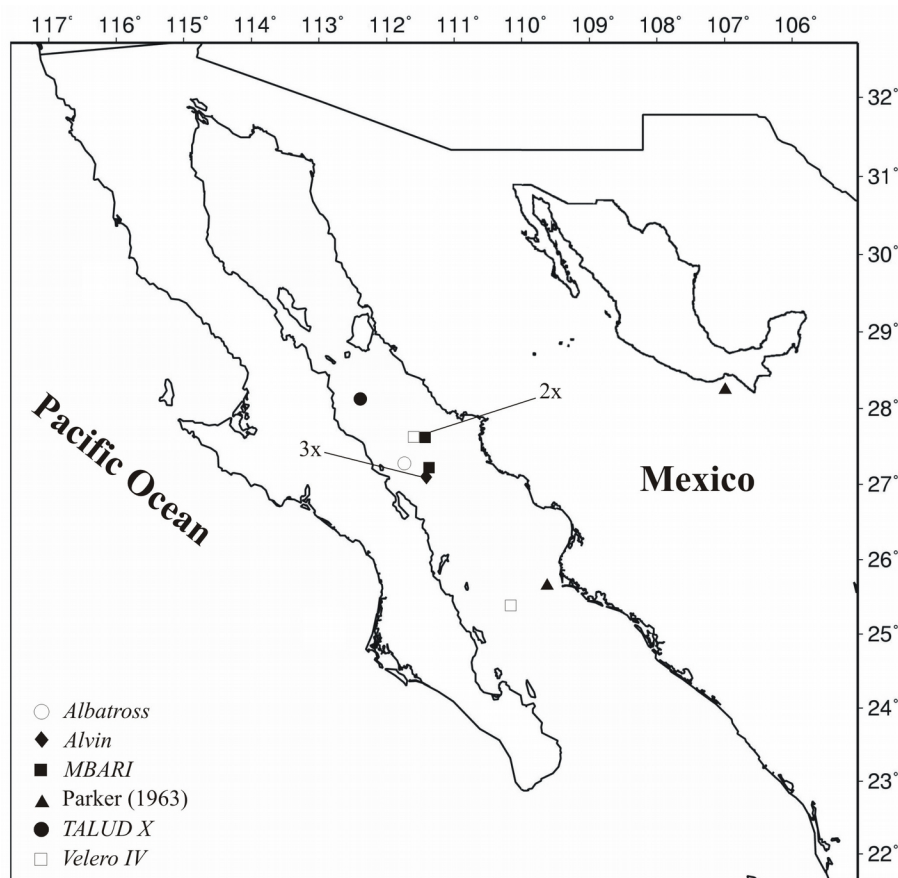


Figure 2. Distribution of "*Pliocardia*" *stearnsii* (Dall, 1895) in western Mexico (Gulf of California only). Data as cited in the text and in Table I. 2x and 3x indicate successive sampling at very close localities.

contains two lots of this species, originally cited by Dall (1895b) and including the material from the type locality (USNM-126751, East of San Marcos Island, 27.15°N, 111.7°W, Gulf of California, Mexico, Albatross St. 3009, depth 1567 m), and a lot from off Oregon (USNM-106857, off Tillamook, Albatross St. 3346, 45°30'N, 124°52'W; *vide* Dall 1995b), USA, in 786 fm (1436 m).

Parker (1963) included two records for *C. lepta* (as *Vesicomya lepta*), one for the Gulf of California (st. 53, 25°31.8'N, 109°22.8'W), at 272-920 m (?), and another from south of Salina Cruz, Mexico (St. 127, 15°38'N, 95°18.5'W), in 1006-1135 m depth. Environmental data for the first record are not reliable because of the wide depth range reported by Parker (1963), while the second record corresponds to 8°C water with oxygen concentration of 0.1 ml/l. Goffredi *et al.* (2003) reported one lot from the Guaymas Basin (27°00.2'N, 111°24.6'W), at 2,200 m. The material used by Johnson *et al.* (2017) in their phylogeny analysis is from the eastern Pacific (without further detail), in depths of between 1415 and 2200 m.

The SBMNH collection holds 9 lots (dry

material), 8 from western Mexico and one from off Hippi, Graham Island, British Columbia, Canada, collected in 1698-2431 m depth (Table I). All the specimens from Mexico are from the Gulf of California (Fig. 4).

Size. The maximum known size of *C. lepta* is 65 mm (shell length). Size distribution shows that 75% of the specimens are in the intermediate size range (SL: 13.50 to 23.49 mm), vs. 12% for the smallest and 13% for the larger sizes (Figure 5). Relationship between shell length and shell height is highly correlated ($R^2 = 0.9803$) (Figure 6).

Discussion

Body size in mollusks is an important parameter in a wide range of ecological and evolutionary investigations and it correlated with ecological community structure (Kosnik *et al.* 2006). Although only one sample was available and analyzed in this contribution, it add some interesting data related to size distribution of *Calyptogena lepta* in the Gulf of California, data which could be used for comparative purposes for population of *C. lepta* in other regions or different environmental

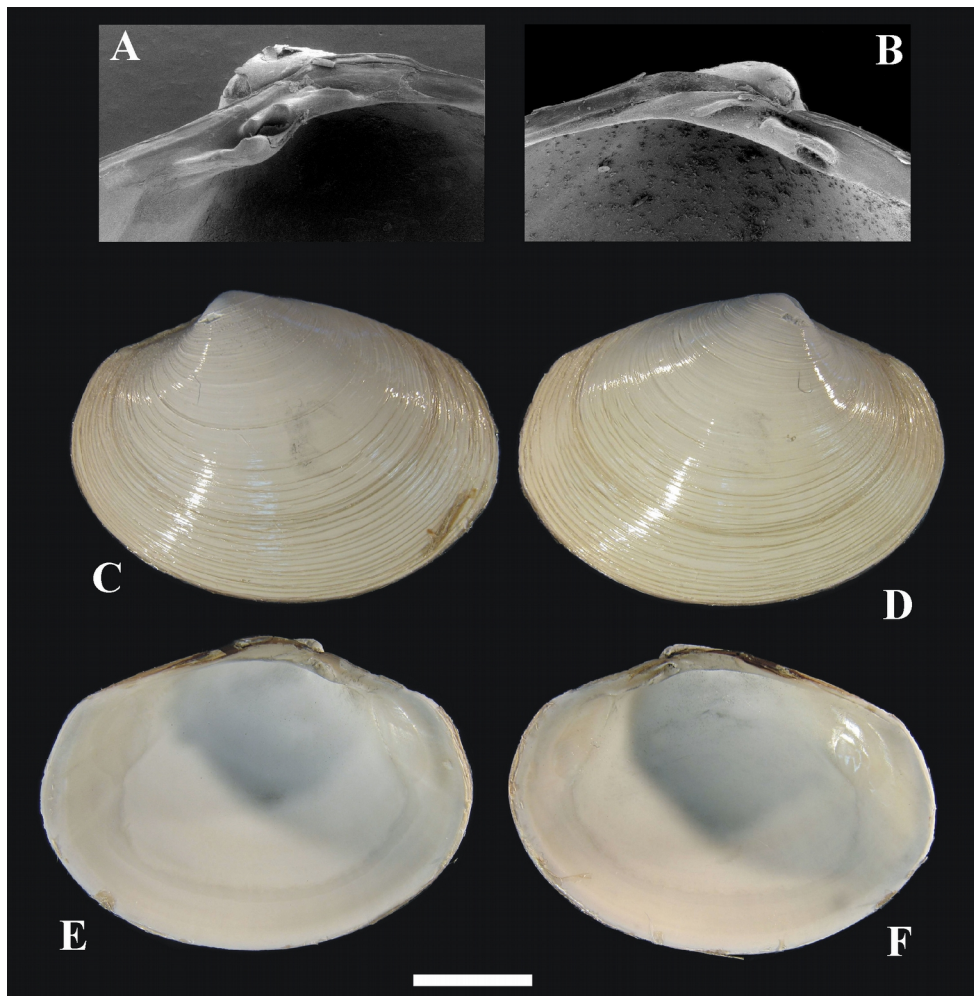


Figure 3. *Calyptogena lepta* (Dall, 1896). A: right valve, detail of hinge; B: left valve, detail of hinge; C: left valve, external view; D: right valve, external view; E: left valve, internal view; F: right valve, external view (A, B, SEM). (SEM, 20 x; C-F scale, 10 mm).

conditions. Morphometric relationships in bivalves, like the one between length and eight obtained for *C. lepta* from the Gulf of California, are important because they also potentially provide comparative data for the same species in other geographic areas (Gaspar *et al.*, 2002).

Species of the family Vesicomidae are essentially found in specialized habitats like hydrothermal vents, cold seeps and sulfide-rich sites (Coan & Valentich-Scott 2012). Both *Pliocardia* and *Wareniconcha* inhabit a wide bathymetric range, from 486 to 3159 m for the former and from 754 to 3010 m for the latter (Krylova & Sahling 2010). The two species reported herein have a wide distribution in the East Pacific, from NW America (Vancouver-Oregon) to the Gulf of California, and further south to the Gulf of Panama in the case of *P. stearnsii*. The present study indicates that these species occur in cold water (3.77°C), just below the lower boundary

of the Oxygen Minimum Zone (OMZ) that characterizes a large segment of their distribution range (Helly & Levin 2004) and can withstand mild hypoxic conditions (in present study: 0.31 ml O₂/l). According to Goffredi *et al.* (2003), *Calyptogena lepta* is typically associated with cold-water sulfide/hydrocarbon seeps, sediment areas around hydrothermal vents, and anoxic basins.

According to records in the Smithsonian collections, *P. stearnsii* and *C. lepta* were previously collected in the same sample, St. 3009 of the Albatross (USNM 756650 and 126751 respectively), East of San Marcos Island, which is located only 95 km from the present record in the Gulf of California (see Fig. 2).

In their molecular phylogenetic study of the *pacifica/lepta* species complex, Goffredi *et al.* (2003) suggested that these species might inhabit different depth strata and that records for *Vesicomya*

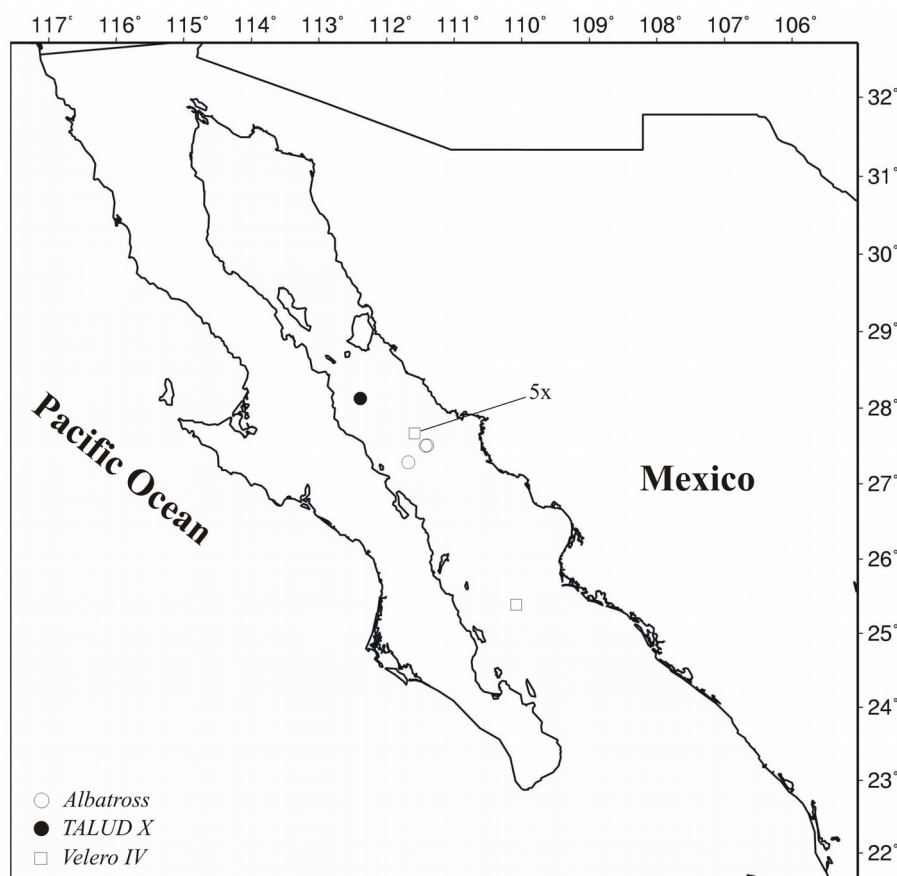


Figure 4. Distribution of *Calyptogena lepta* (Dall, 1896) in western Mexico. Data as cited in the text and in Table I. 5x indicates successive sampling at very close localities.

lepta (= *Calyptogena lepta*) in depths less than about 850 m might actually correspond to *V. pacifica*. However, Krylova & Sahling (2006) emphasized the need for further studies related to the affinity of *lepta* within the Vesicomidae and that there is a need to confirm "that the species investigated genetically [i.e., by Goffredi *et al.* 2003] is actually identical to the type material of *V. lepta*".

According to Krylova & Sahling (2010), morphological characteristics observed in "*Vesicomya lepta*" indicate that it does not belong to the genus *Calyptogena* and probably belongs to the genus *Wareniconcha*, a combination adopted by WoRMS (2018). They emphasize, however, that "in order to resolve the taxonomical position of *V. lepta*, additional studies of the anatomy and the variability of the shell shape are needed". In their recent, comprehensive phylogeny analysis of Vesicomidae, Johnson *et al.* (2017) concluded that "*lepta*" does not belong to *Wareniconcha* and clearly belongs to *Calyptogena*, although these two genera show similarities (i.e., "absence of the pallial sinus, presence of one pair of demibranchs and plate structure of interlamellar septae") (Johnson *et al.*

2017: 353). They also emphasize that "more details on the structure of the siphons are needed to better discriminate between the two genera."

Johnson *et al.* (2017) also included material of *Pliocardia stearnsii* in their phylogeny study and concluded that it belongs to the "*cordata*- group" (4 members) most closely related to *Pliocardia*, distributed in the eastern Pacific and the Gulf of Mexico, and that this group might "also warrant erection of a new genus".

Vesicomid bivalves have been extensively studied in the past several decades. However little has been published on the physical parameters of individual species habitats. We have provided new data on the water temperature and dissolved oxygen content in the habitats of the sympatric *Calyptogena lepta* and *Pliocardia stearnsii*, as well as additional information related to the height/length ratios of these species.

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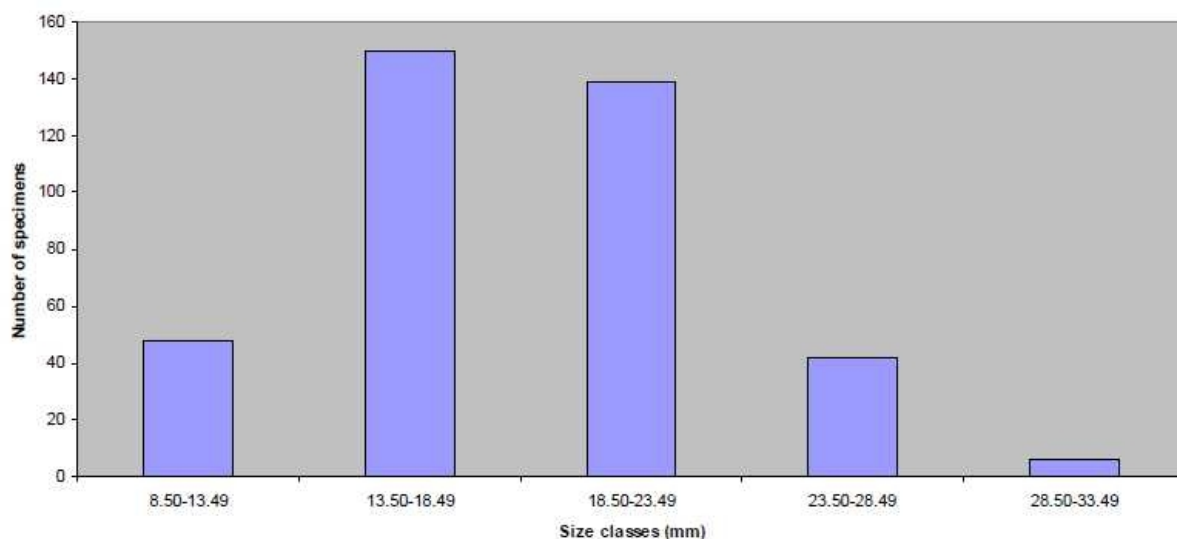


Figure 5. Size (shell length) distribution of *Calyptogena lepta* (Dall, 1896).

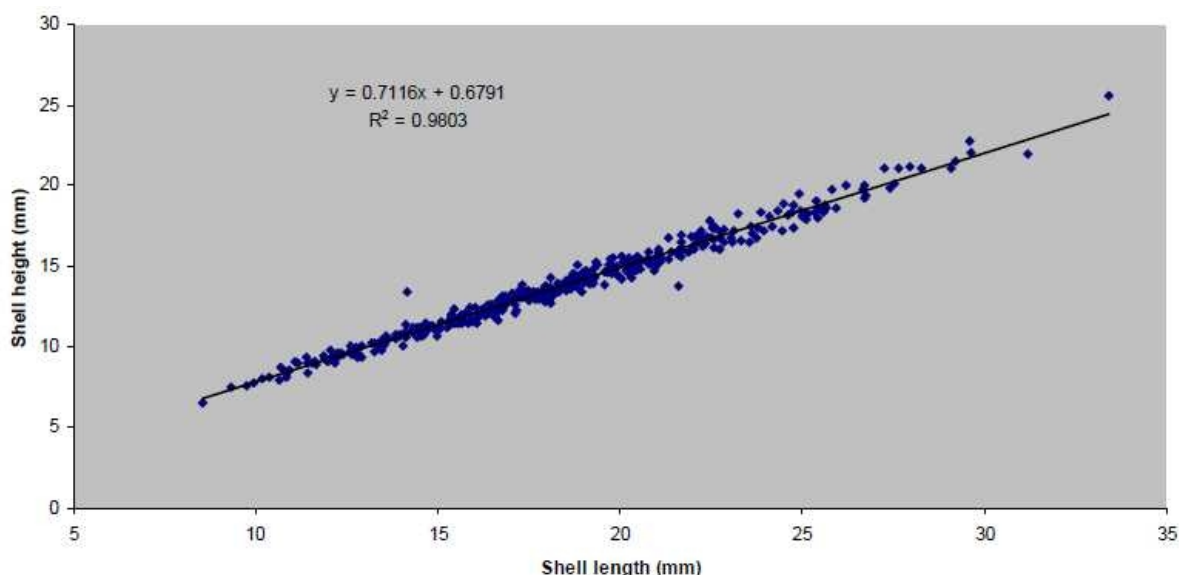


Figure 6. Shell length-shell height relationship in *Calyptogena lepta* (Dall, 1896).

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